MATERIALS PROCESSING

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SURFACE DIAMOND-ABRASIVE GRINDING OF GLASS WITH TOOLS BASED ON PLATE ELEMENTS: FINE GRINDING

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The authors analyze diamond-abrasive tools intended for fine grinding of flat surfaces made of optical glass, glass ceramics, or ceramics, which are based on plate-shaped elements making it possible to vary the space factor of the circular zones and the whole faceplate. The advantages of platelike faceplate elements over spotlike elements are demonstrated based on comparative studies.

Fine diamond grinding (FDG) is usually performed with tools based on spotlike elements of diameter 10 – 14 and height 5 mm arranged along the circular zones of the wheel base. The space factor of "mushrooms" and "cups" for treating spherical surfaces is 0.35 – 0.50, and the space factor of the faceplates is 0.25 – 0.30 [1, 2]. The industrial standard (OST 3-6324–87) [3] prescribes the specific consumption of diamond powder in FDG of surfaces for a wide range of diamond grades, grain sizes, and binders regardless of operating conditions at the level of 2.0 and 8.5 carats/dm^3, for the first and the second passes, respectively.

The authors of [4] analyze five variants of diamond-bearing layers for grinding flat optical surfaces: continuous, spotlike, and formed as Archimedes' spiral, as a logarithmic spiral, and as rays going from the center. Based on theoretical analysis and experimental data the authors [4] draw the conclusion that the tool with the diamond-bearing layer in the form of a logarithmic spiral is optimum (having maximum efficiency and minimum relative wear) (USSR Inventor's Certif. No. 688323) and that grinding efficiency grows in proportion to increasing integral space factor.

According to the technological scheme of producing all types of tools mentioned in [4], needle-shaped diamond grains are positioned horizontally. At the same time, attempts have been made to increase the efficiency of diamond-abrasive grains by orienting them toward the faceplate axis by means of preliminary fixation using special devices or by means of a magnetic field and subsequent fixing using a hardening mixture (USSR Inventor's Certif. Nos. 454991, 592589, 595142, 676436, 724329, 835732, 878555, 891415, 905040, and 906721) [5]. However, these tool have not found practical applications.

It is possible to combine enhanced orientation of diamond-abrasive particles with the possibility of optimizing their layout taking into account the circular space factor by means of using plate-like elements that have shown themselves to advantage during long-term service when arranged in a single or double row along periphery of the wheel for rough grinding of flat surfaces [6]. The same principle has been implemented in the tool for FDG, where plate elements of height 20 – 40, length 12 – 15, and width 1.5 – 3 mm are spaced over the whole field and radially oriented perpendicularly to the surface of the tool body under a space factor of 0.05 – 0.15 (USSR Inventor's Certif. No. 1311921). The binder is a material whose wear resistance is lower than the wear resistance of the bunch of plates, and the grain size of the abrasive filler in the amount of 10 – 50 vol.% is lower by 1 – 2 degrees than the size of the diamond-abrasive grains in the plates. Technological discharge grooves made on the working surface of the tool are directed from the center to the periphery.

The use of spotlike and platelike tools in identical FDG conditions demonstrates the advantages of the latter [7, 8]. The data in Table 1 are obtained in two-sided single-pass grinding on a PD-500MSh grinder with the rotational speed of the eccentric cylinder equal to 60 min^{-1} and a pressure of 0.012 MPa. The experiment involves grinding seven parts of diameter 120 mm treated in a cassette; the parts are made of glass K8 with initial roughness of $R_a = 0.15$ μm. The space factor of the grinding wheel of diameter 500 mm on spot elements is 0.25 and on plate elements it is 0.07. It can be seen that under equal glass removal on each side, the working capacity of the spots after 4 h operation becomes 18 times lower and virtually stops after 6 h of operation. Within the same time the removal of glass using plate-shaped elements

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TABLE 1

Treatment duration, min	Removal of material, μm, by elements			
	spotlike*		platelike**	
	on two sides	on one surface per 1 min	on two sides	on one surface per 1 min
10	15	0.750	20	1.0
30	30	0.750	60	1.0
60	50	0.330	120	1.0
120	70	0.170	200	0.67
240	80	0.041	400	0.83
360	Removal of glass actually stops		600	0.83
480			800	0.83
600			1000	0.83

* Diameter 14, height 5 mm, diamond powder ASM, grain size 14/10, concentration 6%, binder M3-15-5.

** Height 20, length 15, width 1.5 mm, diamond powder ASM, grain size 7/5, concentration 12.5%, binder M3-15-2.

TABLE 2

Parameter*	Grinding elements	
	spotlike**	platelike***
Removal of material per grinding cycle, mm	0.03 – 0.08	0.15 – 0.20
Duration of stable treatment, h	1.0 – 1.5	8.0 – 16.0
Specific consumption of diamond powder, carats/dm^3	8.0 – 10.0	0.7 – 1.0

* Treatment duration 50 ± 10 sec.

** Diameter 14, height 5 mm, diamond powder ASM, grain size 20/14, concentration 6%, binder M3-15-2.

*** Height 20, length 15, width 1.5 mm, diamond powder ASM, grain size 20/14, concentration 12.5%, binder M3-15-2.

decreases by 20% and then continues constant for 10 h of grinding.

Comparative testing on ShPS-350M grinder (Table 2) were conducted in a single pass using a tool of diameter 410 mm on the spindle of the grinder with a rotational speed of 349 min^{-1}. Testing was performed on a block 300 mm in diameter consisting of six plates made of glass LK5 with a surface area of 0.06 m^2 and initial surface after treatment with diamond AS15 of grain size 250/200. The unit pressure was 0.08 ± 0.02 MPa for the platelike tool with a space factor of 0.15. For the spotlike tool the unit pressure was half as much due to a higher space factor.

The results of grinding plates made of KO1 ceramics performed in two passes with grinding duration equal to 15 min are shown in Table 3. It can be seen that the tool with plate diamond-abrasive elements on metallic binder (TU 3-1660–88) has significant advantages over the spot-shaped tool (TU 3-269–84): the abrasive capacity increases 1.5 – 2 times, the steady work without loading is over 5 times longer, and the specific and linear resistance are 5 – 8 times higher. The high milling potential of the plate-shape tool in

TABLE 3

Parameter	Grinding elements	
	spotlike*	platelike**
Diamond powder:		
first pass	ASM (28/20)	ASM (28/20)
second pass	ASM (14/10)	ASM (7/5)
Surface roughness:		
R_a	0.05 – 0.10	–
R_z	–	0.023 – 0.063
Duration of polishing, min	132	45

* Diameter 14, height 5 mm, diamond powder ASM, concentration 6%, binder M3-15-2.

** Height 20, length 15, width 1.5 mm, concentration 10.0 – 12.5%, binder M3-15-2.

some cases makes it possible to modify the technological procedure taking into account rough grinding: one can reduce FDG to a single pass or perform the final pass with a fine fraction of diamond powder (10/7 – 5/3). This, in turn, makes it possible to improve the treated surface to roughness class 13 and, accordingly, to shorten the polishing duration and improve the production of precise optical surfaces, including two-sided treatment [9].

The lubricant-coolant used in FAG was a 0.5 – 1.0% aqueous solution of a concentrate with surfactant, anticorrosion, and antiseptic additives. Glasses with abrasion hardness over 1 were treated using lubricant-coolant SM7/33 (Sapfir 33/4) and glasses with hardness below 1 were treated with SM3/33 (Sapfir 33/1) (USSR Inventor's Certif. Nos. 1453888 and 1459224) [10, 11]. The long-term application of these lubricants revealed no toxic or corrosion effect.

The advantages of plate-shape elements can be attributed to a number of factors. During the production of diamond-abrasive plates the molding pressure is perpendicular to their larger plane; therefore, grains with even a slight asymmetry undergo mechanical orientation: their long axes become oriented perpendicular to the vector of compression forces, i.e., along the larger side of the plate. Inserting the plates on the narrow plane enhances the abrasive capacity of partly oriented diamond-abrasive grains. Their uniform distribution along the height of the element ensures the more uniformly constant milling capacity of plates, compared to spot elements.

The optimal width of the plates equal to 0.5 – 3.0 mm was found experimentally and in the case of the radial arrangements of the plates it ensures the smallest vector and the least contact of the treated part with the plate element. This is equivalent to the self-sharpening mode, where glass and binder waste adsorbed on the working surface of diamond-abrasive elements are not retained on the narrow edge and become torn off by parts being treated, thus revealing the edges of diamonds protruding from the binder and preventing the loading of the wheel and, accordingly, decreasing the number of required dressings of the tool and the probability of scratches.

TABLE 4

Tool diameter, mm	Diamond powder ASM*		Number of tools considered, units	Specific consumption of diamond powder, carats/dm^3	
	grain size	concentration, %		average	range
410 – 350	28/20	12.5	78	1.18**	0.26 – 2.59
270 – 220	28/20	12.5	96	1.05**	
270 – 220	20/14	10.0	66	1.12	0.31 – 2.49

* Binder M3-12.

** Total 1.11 carats/dm^3.

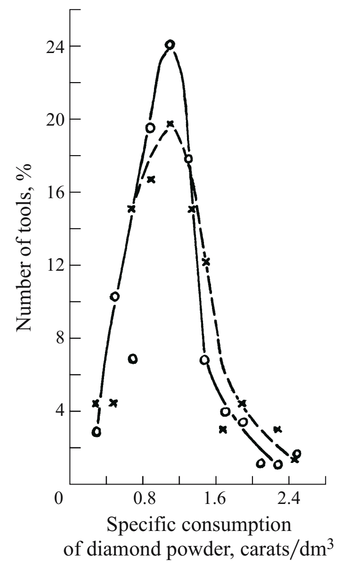

Fig. 1. Normal distribution density curves of diamond specific consumption in fine grinding of flat surfaces using wheel on plate elements with powders of grain size 28/20 (○) and 20/14 (×).

The low space factor of the faceplate increases the abrasive capacity of the tool, since by increasing the unit pressure on diamond-abrasive grains it makes it possible to utilize more fully their cutting capacity under a relatively low static pressure.

The analysis of application of plate-shaped tools in industrial conditions during 10 years is given in Table 4 and in Fig. 1. The FDM was implemented in a single pass treating from 6 to 1 glass parts made of glass K8, K108, K100, LK105, and IKS970 on a ShPS-350M machine with a rotational speed of the spindle equal to 527 min^{-1}, with 29 double swinging passes of the carrier and pressure equal to 0.1 – 0.3 MPa. Faceplates of diameter 410 – 350 mm were fastened to the spindle of the grinder, and tools of diameter 270 – 220 mm were placed on the carrier above the parts treated. The plate-shaped elements were inserted radially, in each zone the distance between the plates being equal. In particular, wheels of diameter 350 mm have 177 elements of height 20, length 15, and width 1.5 mm that are arranged in the zones starting from the center: first zone) 10, second zone) 19, third zone) 28, fourth zone) 35, fifth zone) 40, and sixth zone) 45, with the space zonal factor about 0.070 and the space factor of the whole faceplate equal to 0.055.

The obtained average values of specific powder consumption are significantly lower than the values prescribed for spot-shaped elements. The long-term industrial practice of FDG using tools based on plate elements contradicts the statements of the authors in [4] on grinding efficiency growing in proportion to the integral space factor of the tool and the uniformity of the wear of the diamond-bearing layer with a constant concentration of grains under a zonal space factor inversely proportional to the square of the radius.

It can be seen from the data in Table 4 that the mean specific consumption of diamond ASM of grain size 28/20 is lower by nearly 10% when the tool is positioned above. With equal mean values for fractions 28/20 and 20/14, the specific values of individual tools are lower for finer grains and their variance is slightly higher (Fig. 1).

Thus, using wheels with plate-like elements for fine diamond grinding makes it possible to vary their total and zonal space factors for particular operating conditions. These wheels have increased milling capacity, are steady in operation, have an extended service life, a lower specific diamond consumption, and lower powder losses due to the decreased number of tool dressings required and to insignificant waste generated by the elements.

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